BTeV/C0

BTeV Temple Review: EM Calorimeter

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3/30/04

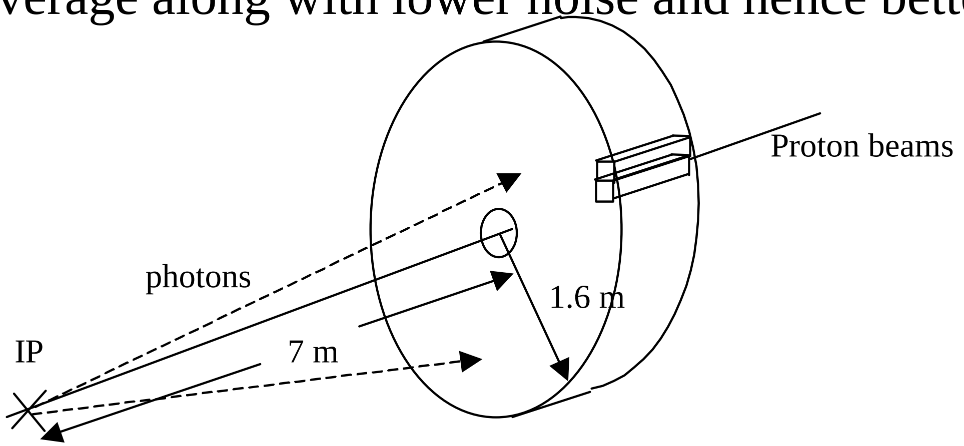
Outline

- Why EMCAL?
- How is it made?
- Who?
- R&D Highlights
- Cost
- Summary

Why is a good calorimeter needed

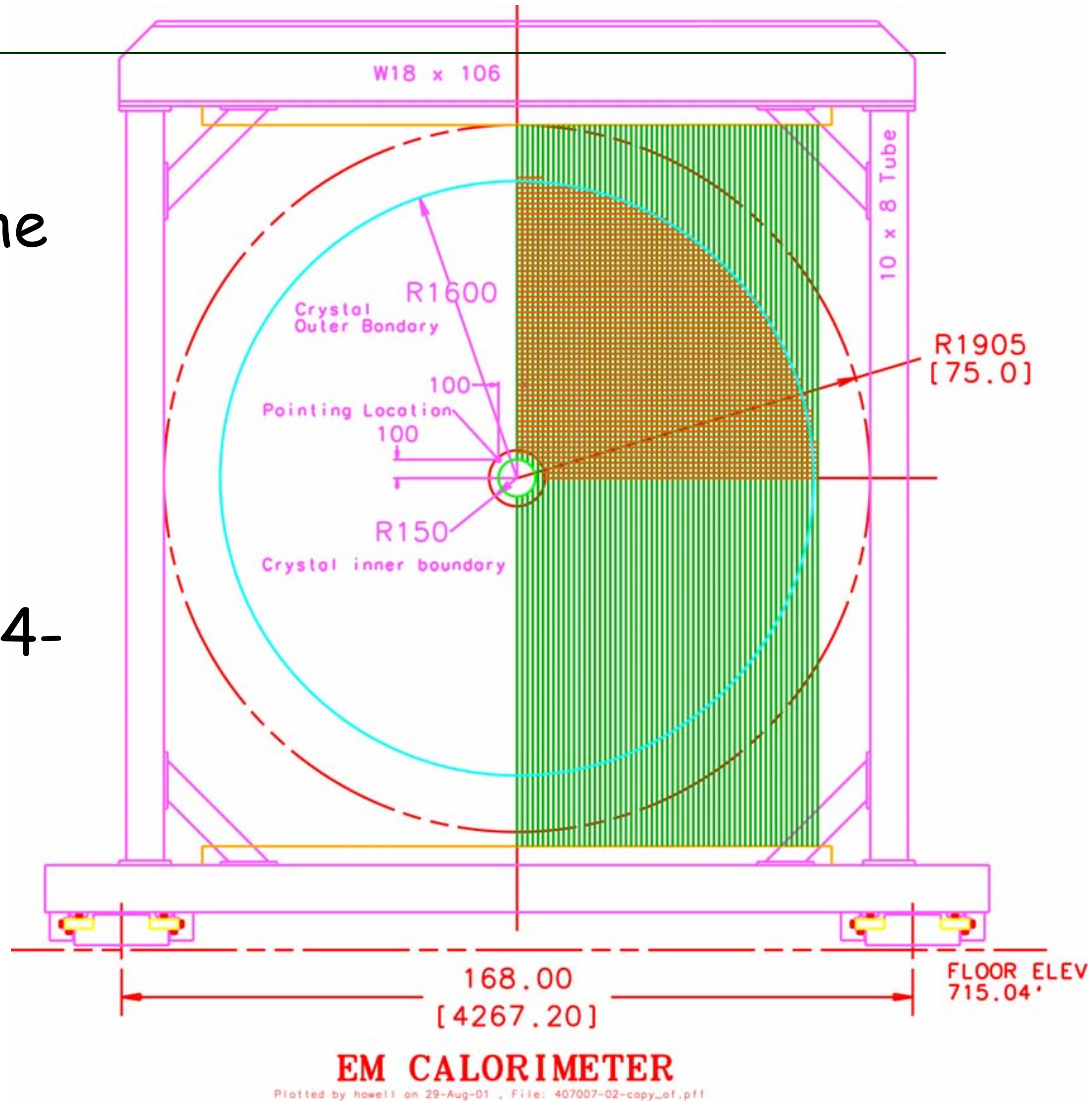
- Many of the measurements require π^0/γ detection:
  - radiative penguin decays: $B\to\rho$ (or K^*)γ
  - $B_S\to(J/\psi)\eta^{(')}$,(sin2χ, $\Delta\Gamma_S$)
  - isospin analyses to disentangle penguin, tree contribution in "one" decay mode:
    - $B\to\rho\pi$ (sinα & cosα)
    - $B\to K\pi$ (sinγ)
- A major distinguishing feature wrt LHCb

- Lead Tungstate Crystals (requirements similar to CMS).
  - Excellent energy and spatial resolution.
  - Fast – no tail in the next crossing
  - Compact – minimum shower overlap
  - Rad hard – survive hadron machine environment
- PHOTOMULTIPLIER tubes instead of avalanche photodiodes and vacuum triodes (CMS uses) because there is no B field. We will get better photocathode coverage along with lower noise and hence better energy resolution



Mechanical support: Front view

- 10100 PWO crystals: 28×28×220 mm^3 (at the back).
- 10100 1-inch 6-stage PMT's.
- 8-bit 8-range ADC (QIE's) connected *via* 4-m cables



BTeV/C0 Design and prototype

- Gave up CMS-endcap design (carbon fiber cells) – expensive, not needed.

Successful

Good for cost & estimates

Ecal group consists of

- Minnesota – Kubota, a few Undergrad and grad students
- U. of Belarus (bring CMS experience)
- IHEP, Protvino, Russia (many active physicists; has U70 – test beam facility)
- Nanjing, USTC, Shandong
- Northwestern – Jerry Rosen
- Syracuse
- FNAL inc. engineers (EE/ME) & techs

Past R&D results

- Resolution
- Radiation hardness of PWO (and other components)
- Calibration system

- Due to huge efforts by IHEP physicists at their test-beam (and test bench) facility.

- Mechanical structure
- MC –
  - electron rates for calibration;
  - radiation levels
- Radiation hardness of optical glue – 10 qualify
- Radiation hardness of wrapping materials – Tyvek, Teflon and aluminized Myler all work

Recent R&D activities

- Electronics (yet another QIE!) FNAL EE is working on it – expect the prototype submission in May
- FEB to utilize QIE prototype in FNAL testbeam is on-going.
- Detail study of light calibration system – stability (0.1% over a few days) and pulse-to-pulse variation (0.2% - need a few pulses to get good calibration).
- Source based measurements of radiation tolerance of crystal for QA is moving forward at IHEP – talk at breakout session.
- Light calibration system prototypes.
- MC studies of feasibility of muons for calibration.
- Impact on physics of worse calibration (1% instead of 0.5%)

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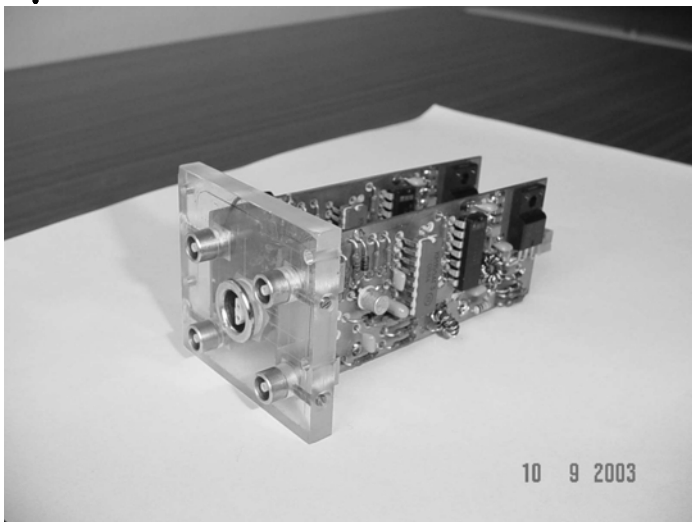
R&D Results - publications

- T. Brennan *et al.*, “The BTeV Electromagnetic Calorimeter,” NIM **A494**, 313 (2002).
- V.A. Batarin *et al.*, “Development of a Momentum Determined Electron Beam in the 1-45 GeV Range,” NIM **A510**, 211 (2003).
- V.A. Batarin *et al.*, “Precision Measurement of Energy and Position Resolutions of the BTeV Electromagnetic Calorimeter Prototype,” NIM **A510**, 248 (2003).
- V.A. Batarin *et al.*, “Study of Radiation Damage in Lead Tungstate Crystals Using Intense High Energy Beams,” NIM **A512**, 484 (2003).
- A. Borisevich *et al.*, “On the Radiation Damage of BTeV EMCAL Detector Unit” hep-ex/0212053 (2002).
- A. Uzunian *et al.*, “Comparison of radiation damage in lead tungstate crystals under pion and gamma irradiation” to be published in NIM.
- A. Ryazantsev *et al.*, “LED monitoring system for the BTeV lead tungstate crystal calorimeter prototype” to be published in NIM.

Light pulser

- Based on LED's
  - Pointed out as a weak point (costing) in the last Temple review.
- Both Minsk and IHEP groups have built prototypes (IHEP, based on our experience at the test beam and Minsk, based on CMS experience)

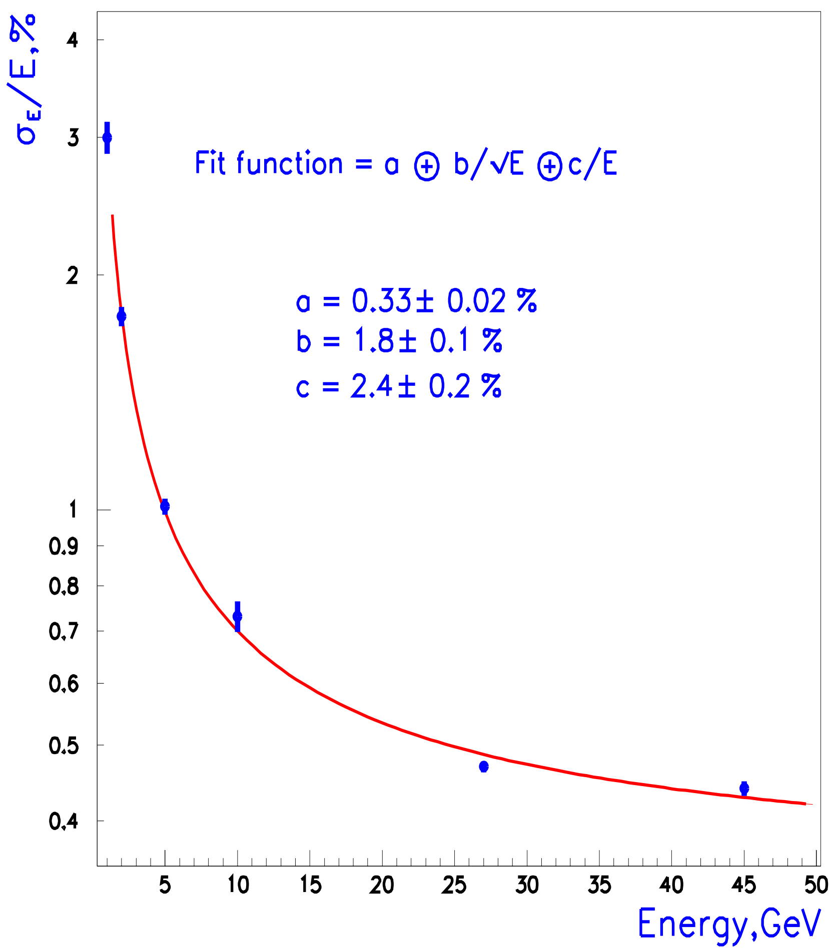


Test beam studies at IHEP, Protvino

- Used beam to irradiate crystals <u>and</u> monitor light output.
- Used both electron and pion beams
- Resolutions
- PWO survives radiation
- Crystal responses to radiation
- Studies monitoring system using light pulser
  - Use both blue and red LED's
  - Red LED monitors PMT gains
  - Blue LED monitors crystal transparency and PMT gains

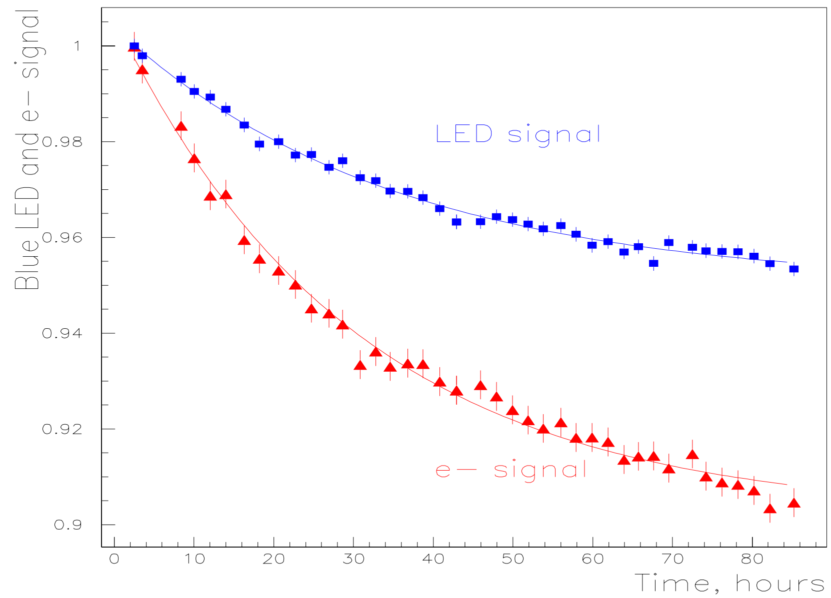
Test beam Results: Energy Resolution

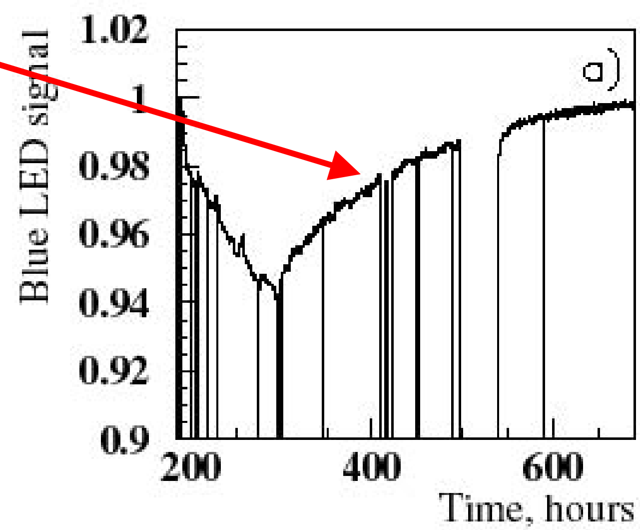
- Agreement with our Monte Carlo prediction
  - constant term (a) (uniformity and shower leakage), and
  - stochastic term (b) (shower leakage and photon stat. [~ 5 p.e./MeV])
  - "noise" term (c) is actually due to momentum measurement error of electron beam due to multiple scattering



Light loss from Radiation

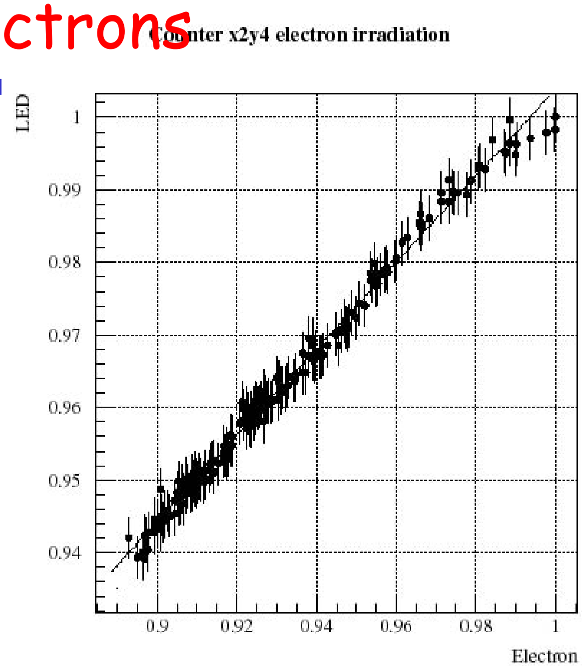
- Light loss (at dose rate of 15 rad/h) is exponential and saturates.
- Confirmation of damage recovery mechanism
- Time constant of loss is ~30 hours.

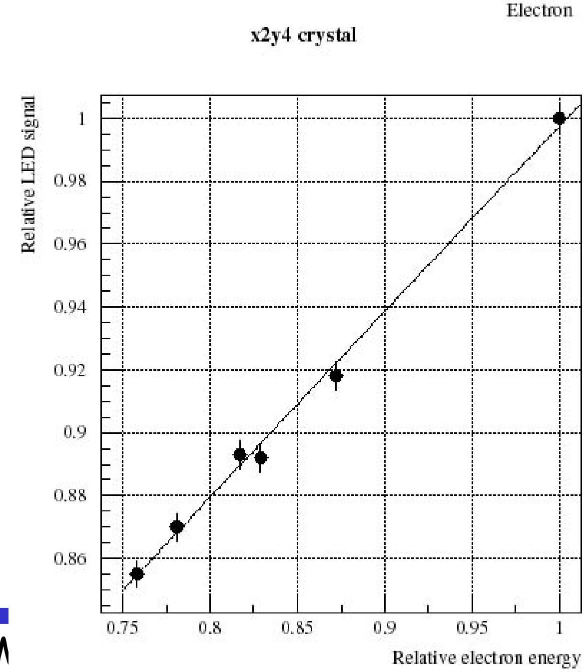




Correlation: LED *vs* Electrons

- The ratio of their changes (or slope of the graphs) is important to know.
- Then we can correct the particle data using LED data.





Cost estimates

- Sensors (PWO crystals, PMT's, others) - \$8.2M
- Electronics – \$2.2 M
- Mechanical structure – \$1.0 M
- Installation, integration, testing - \$0.55 M
- Management – \$0.3 M
- Total – \$12.2 M
- Contingency: 4.1M/33.4%, for a total of \$16.3M

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Crystal Cost

- CMS has used only Bogoroditsk crystals.
- CMS endcap may be produced at Apatity and/or Shanghai
- Our studies demonstrate both Shanghai & Bogoroditsk crystals are equal in quality.
  - Both have good track records of crystal mass production.
- Apatity crystals (ALICE size) work well (inc. radiation tolerance).
- We will choose the final vendor(s) based on final quotes
  - We are working with 4 vendors now.

Basis of Estimates

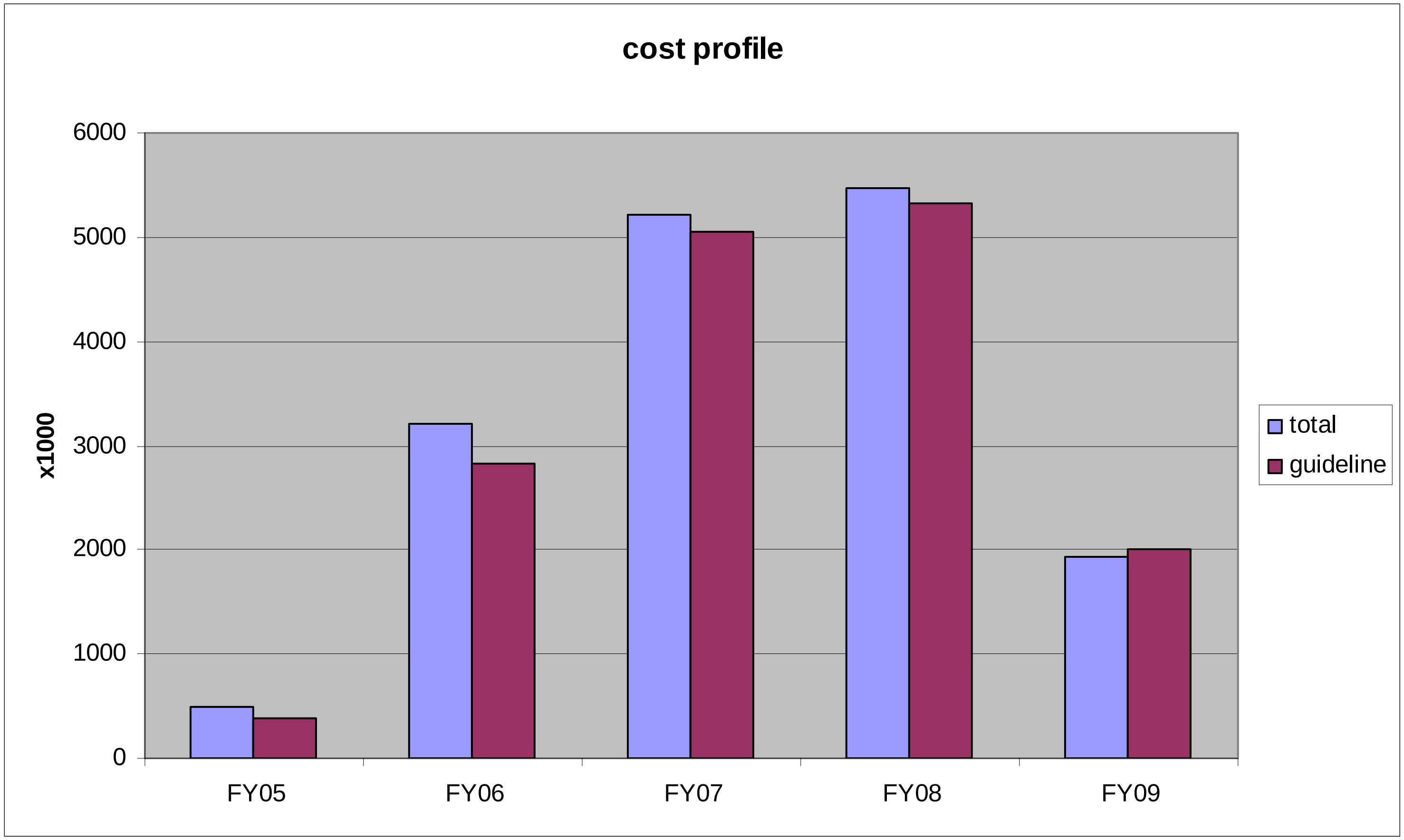
- Quotes (PWO, PMT's, some electronics and mechanical parts)
- Prototyping (mechanical structure)
- Engineering experience of similar projects at FNAL (PC boards, cooling system)
- CLEO experience (acceptance tests, insertion of crystals, final testing)

Summary

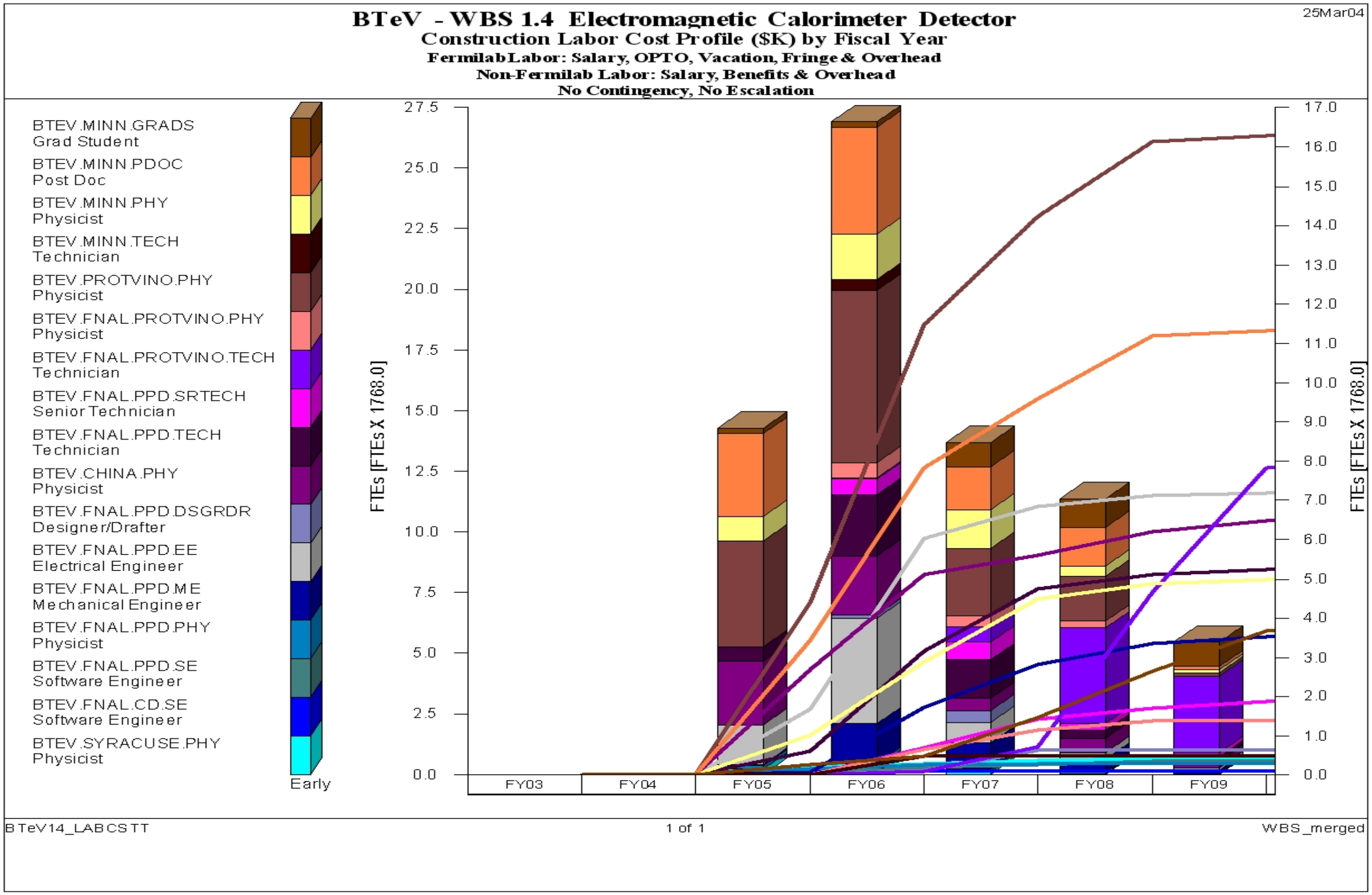
- EMCAL is an important component – much better than LHCb's.
- Significant R&D has been done – ready for costing and scheduling
  - resolution, radiation effects, calibration, good and cheap crystal support.
- We want to carry out a few more studies this FY.
  - Calibration (more test beam/test bench studies)
  - Electronics (QIE: prototype run soon, FEB boards – testbeam version being worked on)

End

Cost profile



FTE needs



BTeV - WBS 1.4 Electromagnetic Calorimeter Detector
Construction Labor Cost Profile ($K) by Fiscal Year
Fermilab Labor: Salary, OPTO, Vacation, Fringe & Overhead
Non-Fermilab Labor: Salary, Benefits & Overhead
No Contingency, No Escalation
25Mar04
BTEV.MINN.GRADS Grad Student
BTEV.MINN.PDOC Post Doc
BTEV.MINN.PHY Physicist
BTEV.MINN.TECH Technician
BTEV.PROTVINO.PHY Physicist
BTEV.FNAL.PROTVINO.PHY Physicist
BTEV.FNAL.PROTVINO.TECH Technician
BTEV.FNAL.PPD.SRTECH Senior Technician
BTEV.FNAL.PPD.TECH Technician
BTEV.CHINA.PHY Physicist
BTEV.FNAL.PPD.DSGRDR Designer/Drafter
BTEV.FNAL.PPD.EE Electrical Engineer
BTEV.FNAL.PPD.ME Mechanical Engineer
BTEV.FNAL.PPD.PHY Physicist
BTEV.FNAL.PPD.SE Software Engineer
BTEV.FNAL.CD.SE Software Engineer
BTEV.SYRACUSE.PHY Physicist
Early
FTEs [FTEs X 1768.0]
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
FY03
FY04
FY05
FY06
FY07
FY08
FY09
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
FTEs [FTEs X 1768.0]
BTeV14_LABCSTT
1 of 1
WBS_merged

Temple 2003

- Study the relative crystal-to-crystal response to blue LED light and the correlation to radiation damage of the crystals. Understand better how to apply these corrections to BTeV running conditions.
  - Much has been accomplished (NIM A512(2003),pp 484-501)
  - More recent work will be described in the breakout session.
- Calculate the impact on physics processes due to deterioration of components due to radiation damage.
  - Small because only crystals near the beampipe (12% - more than 18 rad/hour) will be affected significantly by radiation

Temple 2003 (cont'd)

- Cont'd
- If constant term in the resolution is as bad as 1% (compared to 0.55% we are shooting at), the mass resolutions, efficiencies may suffer 10%)

- Estimate the amount, cost and schedule of new components needed to be replaced if radiation damage deems them unusable.
  - We will not replace crystals in very high radiation area since their use is limited to detecting high-energy photons. This is because particle background in these crystals are high and it is not practical to try to detect photons as low as 1 GeV. So damaged crystals are good enough.
  - We will use spare crystals if something happen to crystals in less radiation intense areas. Use ~1 week access period.

Temple 2003 (cont'd)

- Continue to test all detector samples, especially PMTs from various vendors and with different windows, in a BTeV equivalent radiation environment.
  - Need to be done at the Booster facility
- Continue to try to solicit additional US physicists.
  - Yes, we are trying.